

**CURRENT DISCUSSIONS ON DIGITAL SKETCHING TOOLS IN THE EARLY STAGES
OF ARCHITECTURAL DESIGN IN EDUCATION**

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Abstract

In the architectural design, designers are focused on the early stages of the design process or conceptual design. The ultimate goal of this stage is to find a solution for an existing problem, investigate design space, or explore an idea. This stage conventionally begins with sketches and diagrams to explore ideas and solutions; the ambiguity and vagueness of conventional freehand sketching can be a source of creativity.

Nowadays, with the advances in digital technology, there are attempts to integrate digital tools into the conceptual design in order to construct a digital design medium in the architectural education. Recent developments in CAAD software shows a shift in focus toward conceptual design interface; but these tools have not developed and still fail to offer an appropriate design environment for sketching; So application of digital tools in the early stages of design, has created problems and challenges especially regarding to creativity. Therefore, this research focuses on the early stages of the design process and investigates the current situation of digital sketching and its related discussions and challenges in architectural design education. Findings show that there are attempts to study and propose interfaces and programs to enhance digital systems or new ways of working with them in order to support creativity and sketching. Also findings indicate that the professors yet doubt over digital tools, but there is a tendency to use these tools among educators and their students if these tools can meet educational demands.

Key Words: conceptual design; digital sketching; creativity; pen based sketching

1. Introduction

With the revolution of computer technology, more software are developed, which have been utilized in many ways including drafting, design, simulation, analysis, and manufacturing to visualize in three dimensions and to simulate aspects of performance and the coordination and control of production information [1], [2]. Nowadays, the digital technology began to affect the thought process of the designer; therefore, digital technologies are now enabling a move from drafting and visualisation to the generation and optimisation of design [3]; but, existing conventional digital software does not yet support the early conceptual design phase thoroughly [4].

When computers are not commonly used in conceptual design phase, many architects use pen and paper and model making to express their designs and presentations; while in architecture schools, many, if not most, architectural students start their earliest design experiences quite naturally by using the computer [5]. However, today due to the low willingness of professors to use this technology, programs fully based on digital technology are not available in training.

1.1 Literature Background

Thinking in sketching digitization started decades ago with SketchPad presented by Sutherland. From this date, a body of work was presented to enhance this direction of research [6]. According to background of the research issue, the literature can be studied in several areas from different points of view.

Some researches (e.g. Rauhala [7], Dokonal & Knight [8], Verstijnen et al [9]) review and explore the role that computers can play in the early design stages and sketching process. Some studies such as [1], [2], [3], [9], [10], [11] also focus on searching and discovery of sketching behaviours and opportunities to support creative designing by using digital technology.

Other research (such as [3], [12], [13], [14], [15], [16]) describe current digital sketching programs - sketch-based and pen-based interface- to explore essential elements of sketching and focusing on their support for problem solving. Some studies such as [6], [17], [18], [19], aim to develop a

sketching environment to feel as natural as sketching on paper to improve and enhance idea generation process.

Therefore the purpose of this paper is study the status of digital sketching in early design stages and their current challenges in the educational field especially regarding to creativity and why computers are not yet commonly used in the early phases of architectural design. Also by studying and investigating current digital sketching tools attempts to find out recommendations for developing digital interface to support sketch and creative design process. So, the study consists of three main sections; the first section outlines current discussions about the digital technology in the early stages of design and especially regarding to creativity; the second section describes and reviews the digital sketching tools especially pen based systems and in the third section a pilot study is conducted to show the current situation in architectural schools in real world.

2. Current Discussions

2.1 Digital Sketching in Architecture Education

While digital media is spreading rapidly in design education, the value of using traditional or digital media and tools has been the subject of debate among design educators [20]. In recent years, when reviewing design education, educators have been confronted with the polemics of hand versus computer, or traditional versus digital media. It seems that, the conservatism and anxiety of instructors toward using digital tools in teaching is natural because, the senior instructors have not ‘grown up’ with computers which makes them have unfavorable attitudes toward computers.

Dorta [21] states, “The problem here is that in the architectural schools, ideation is still done as it has been since the Renaissance, by traditional analog manual tools, like sketches and physical models, without real support from current digital tools.” Some researchers such as Norman [22] believe architecture education courses require a transition from a completely analogue system of representation to one of complete computer immersion, that he calls it “paperless studio”. In contrast, Lawson [1] notes “mounting evidence that CAD infiltration in design education is resulting in good design skills being supplanted by good computer skills”; he argues that, “it has always been possible

to find excellent presentation combined with poor design. However, before the advent of CAD, it seldom happened in practice.”[1].

And finally four criteria of Daru [23] that posed for the assessment of computer based sketching that answer of them will open new contexts to discussion:

“- is computer sketching didactically correct? The ultimate goal is to learn designing rather than producing the nice or pleasing pictures;

- is it useful? The answer is positive if it gives additional possibilities for the idea production in designing or if it shortens the learning time of design sketching;

- is it sufficient? Can hand sketching be replaced by computer sketching entirely?

- is it harmful? Are such exercises detrimental to traditional sketching experience?”

2.2 Digital Tools in Early Stages of Architectural Design Process

Recent developments in CAAD software shows a shift in focus towards conceptual design interfaces; but, according to some researchers, these tools have not developed and still fails to offer an appropriate design-oriented environment for design sketching [5], [24], thus, designers abstained from using CAD systems to sketch and still do sketching using pencil and paper [6], [18]. Pranovich [17] believes that, in the early stages of design computers manifest their inability: “they are inflexible, unimaginative, and tedious; and they support focuses on quantitative rather than qualitative support”. According to Lawson [1], “computers are poor at recognition, interpretation and the reconciliation of conflicting demands”. Daru [23] too states that, “computers are not offering an adequate environment for design sketching”.

In contrast, the suggestions of different researchers indicate that, digital media have elevated the mental ability of the designer to visualize and evaluate abstract ideas as a facilitator of design ideas, but is not a creator of the content. According to Mohd et al [25], the integration of digital technology in the design process increases the number of ideas in the synthesis activity, and enhances students' desire to gain more knowledge and design ideas.

Therefore, in order to comprehensively assist designers to produce more stimuli for their designs in the conceptual stage, computer-aided conceptual design (CACD) was gradually explored and developed [14], [26]; the disadvantages of the current state of CACD indicate that few digital tools exist to address the early phase of the conceptual design [26].

This situation may result from the abilities of most current computer-based sketching systems. They due to interface and accuracy are often non-dense and unambiguous in representations and do not allow abstractions and uncertainty that potentially impede transformations, which play an important role in the conceptual design process [26], [27]. Indeed, the mechanical nature of digital techniques and structured CAAD environment [12] have constrained their application during the early stages of design; and as discussed by Bilda & Demirkan [20], the design apprentice software was not suitable for the conceptual design process, as it lacked support for designers' habitual activities such as doodling and sketching activities.

On the other hand, the interaction between designers and machines is not sufficiently intuitive so that the use of a digital system does not match the development speed of thought and idea while in traditional sketching, the pen is a natural extension of the hand, so conscious efforts in using the computer shifts the attention away from the actual design process [19]. Currently, CACD systems are based on a digital sketching environment that mimics free-hand sketching behaviors, so, according to Tang & Gero [26], a dense and ambiguous representation for CACD is still difficult.

2.3 Digital Technology and Creativity

As previously noted, current digital media systems apply well in the final and routine phases of design, but the applicability in the early conceptual phases is poor. Additional to previous statements, most researchers believe that the use of computers in the early stages of design may impede the creative behaviors. According to them if a designer starts to use CAAD from the beginning it can limit his creativity and 'can encourage poor design' [10].

Lawson [1] states that, "the problem is that if the computer uses the wrong metaphor for describing design features, it can inhibit the creative integration that design requires in order to be what

Hertzberger calls ‘real’ as opposed to ‘fake’ creativity”. Verstijnen et al [9] have examined ‘combining’ and ‘restructuring’ in sketches as a creative process, and have evaluated 3D CAD programs on these issues. They concluded that they are not helpful as tools for idea generation sketching in the early creative phases of the design process.

Rauhala [7] believes “it seems impossible to use computers as a creative adviser or as a generator of totally new design solutions”. Dokonal & Knight [8] claims ‘that is not true anymore’, and say that modern CAAD software is at least an additional possibility to start a design with clearly new benefits and still some disadvantages. According to Bilda [4] digital systems lack the cognitive aspects of architectural design, thus, trying to use computers creatively seems to be generally impossible.

Several reasons according to researchers are given to explain why digital systems inhibit design thinking and creativity in the design process:

For instance, Lawson [1] states that “the high resolution of CAD representations distract the designers’ attention from whole to detail and limit their ability to see and interpret things in new ways”. According to Dorta & Pérez [27] and Gharib [18] the user interface based on commands, messages, menus, mouse, and keyboard is still hindering the creative flow in ideation and thinking process; because it prevents the designers from focusing and concentrating on the creative thinking [24]. Also, as previously mentioned, digital systems are driven more by production encourage working with precision and details while allowing little room for vagueness and indeterminacies because computer interface (software and hardware), which always demands specific abstract and accurate data; and discourage the designers to modify their ideas resulting in premature fixation due to their inflexibility that limits creativity [27]. Finally, Haapasalo [11] claims, that, it is very difficult to find mathematical algorithms, which can imitate or increase creativity.

Despite to all of these, can be claimed that, there is no reason why CAAD cannot be effective in conceptual design, but it seems that this media can support creativity in the early stages of design. Rauhala [7] believes, “this does not mean that computers would be useless in sketching”. According to him they are not helpful in creativity itself, they can be indispensable in technically validating new ideas. The analysis and findings of Musta’amal et al’s [2] studies, suggest link between the emergence

of creative behaviors and the use of CAD in designing; and according to them “it might potentially encourage creativity in designing”. Mohd et al [25] in their study indicate that CAD technology in the design process can help students to produce creative architectural product. CAD technology can help students in stimulating creative ideas during the design process, because it causes designers to re-think previous ideas and to improve the quality of their designs. Haapasalo [11] believes that, “the computer doesn’t, by itself, influence creativity much; but it has an impact on creative work. It has often been said that with the computer, artists, designers may easily play with hundreds of solutions or variations. Thereby computers may have a supportive impact on creativity”. According to him, the computer can be considered as a machine to achieve a greater ability to think.

3. Digital Sketching Tools

As previously outlined, sketching is generally associated with early, conceptual design and there are ongoing efforts to find out how computers may help in the conceptual phase of design process [4]; therefore, researchers directed into developing sketch-based interfaces for modeling (SBIM) [18], [28].

The idea of sketch-based modeling is not new. It dates back to Sutherland’s sketchpad system. In this system, the user produces 2D drawing by sketching directly on a computer display device using a light-pen [6], [18], [28]. In the last decade, we have seen an explosion of both sketch-based interfaces and pen-based computing devices. Each generation of sketch-based interfaces can be traced to different hardware devices that shaped their inception and evolution: the light pen, the digitizing tablet and stylus combination, later the mouse, more recently tablet PCs and PDAs and multi touch surfaces as well as pen based PC software [28]. Generally, the development of early design tools has relied heavily on sketching input and these tools mimic the traditional architectural environment, simplify interaction with the system and support various design aspects [17].

Also, Sketching support tools¹ can be divided into two classes: *2D sketching support*, for example tools like Cocktail Napkin (Figure 1) [13] and Autodesk SketchBook Pro; and *3D sketching support*,

¹For more study about some of these tools see [34], [51]

for example tools like DDDoolz (Figure 2) [16], and SketchUp. Actually 2D sketching interfaces imitate the pen and paper features. They have disadvantage that provide digital methods for drawing, coloring, and shading which make designers concentrate on the process rather than the idea. For these reason, developing a new 2D sketching interface that uses freehand sketching in the same way of pencil and paper is essential [6].



Figure 1 Electronic Cocktail Napkin environment

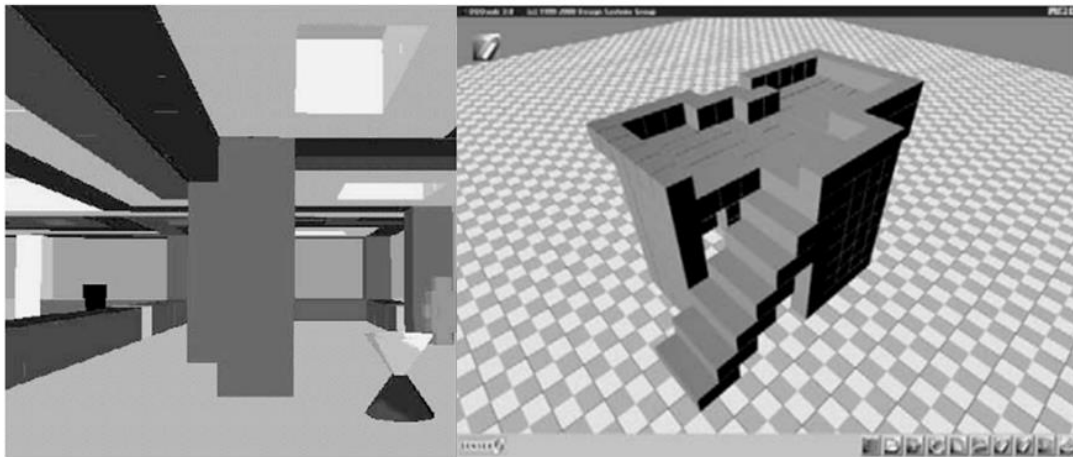


Figure 2 3D sketches are created using DDDoolz [16]

3.1 Pen Based Sketching Systems

As previously cited, the most of designers are still relying on the conventional media– pen and paper. Since these mouse based computer media are incapable of supporting the functions of pen and paper during initial sketch, many researchers (like Hamre [3], Gross & Do [13], Lim, [14], [15]) turned to

the research and development of pen based systems. In 2D pen based systems, instead of using a pencil on a piece of paper, one will use a stylus on a touch screen. The only difference is the design environment. The application was implemented on a for example tablet PC with a pen input device, with a consistent pen-based interface that mimics pencil and paper sketching, but with the assistance of the computer to enhance and augment the process [13], [14], [15], [29], [30].

Since, the emergence of stylus driven “touch-screen” PC tablet hardware, coupled with freehand sketch software; so, the purpose of this system is to provide the CACD (Computer Aided Conceptual Design) system with conveniences and functions like fast expressions of images in designers’ brains, ambiguity, resolution, gesture, and notions [14]. Certainly, the additional of this new technological tool does not threaten traditional drawing; and can help designer to think while designing in the conceptual design stage. The first tablet PC can be traced back to the 1960’s; GRIDPad in 1980’s and in 1990’s ThinkPad tablets are introduced. In 2001, Bill Gates introduced the world to the Windows XP Tablet Edition that included a touch screen and compatibility with the desktop computer. The unveiling of the Apple iPad in early 2010, provided the world with a device that bridged the laptop computer with the smartphone providing ultimate user mobility and flexibility. Today, the digital tablet has the stylus meant to substitute the pen and screen in lieu of a piece of paper [3].

However, what is the advantage of using computers to support sketching when they merely emulate pen and paper tool?

The major added value of such tools in comparison with pen and paper is the facilitation of the transition from the early stage to more definitive stages of design [19]; also, the use of sketching using digital technology as it tends to reduce barriers to creative thinking because it does not rely on activating commands, like on a computer; the paperless environment a digital tablet creates increases flexibility for the user to generate ideas [3]; in addition, in her experiment, all participants felt the digital tablet has immense potential for use in the design process to continue to enhance idea generation. So these Electronic sketch tablets, which, like paper and pencil, support unspecified input are more appropriate electronic idea creation tools [9]. However, according to Lim [14], due to

the cognitive behaviors displayed when using pen-based system and when using conventional pen and paper are different.

3.2 Three-Dimensional Digital Modeling

One of the features and facilities that digital tools have provided to design, especially in the early stages of design, is three-dimensional modeling. The findings of some researches show the importance of integration a 3D modeling to early architectural design phase for producing unique design solutions. In this case, visual design thinking is performed through three dimensional digital models that might be described as sketching in space. Also, according to Haapasalo [11] 3D modeling, from the design point of view is aimed usually at the early phases of design in order to examine and visualize details or larger entities. Using easy to handle 3D modeling software helps to find appropriate design solutions.

Using easy to handle 3D modeling software helps to find appropriate design solutions. For example, the EsQUIsE software provides architects with the possibility to generate automatically 3D views from the freehand drawings that are used for exploring alternative solutions (Figure 3 & 4) [31].

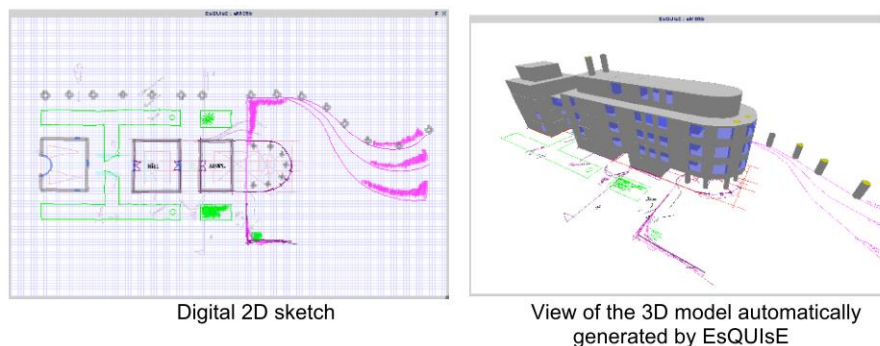


Figure 3 An overview is drawn on a digital layout with an electronic pen. The architect can then select those of the layout which are relevant to him and ask for an automatic generation of the 3D view (at the right) [31]



Figure 4 EsQUIsE is used on a graphic tablet [31]

3D modeling sometimes allows the students to understand their own design better and definitely increases their design abilities in a rather short time [30], and this digital model has a good visual impact and gives freedom to the architect to think about objects, space and form on the same screen [25]. But today there may be problems with three dimensions digital modeling, because, digital modeling introduces new possibilities that allow manipulation of forms, while having fewer cognitive roles. This is why digital models are considered as a threat in design; and according to Lawson [1] “some of 3D forms are relatively easy to generate in CAD but are hard to represent in manual perspective. Perhaps this encourages students to believe that because they have drawn something infrequently seen, they are being creative”.

3.3 Recommendations for Digital Interface for Supporting Sketch

Researches which attempt to find knowledge for designing sketch based user interface, offer recommendations for supporting digital sketching tools in conceptual design. One possibility in developing user interfaces is move in a more flexible direction and more close to the natural and traditional architectural design process, and provides benefits not available with paper, such as the ability to simulate the system to support creative design work [11], [29].

To provide an interface that feels natural yet interprets sketches as the user draws, the system must be able to resolve ambiguities without interrupting the user [13]. Lawson [1], [10] states two conditions; *first*, “the computer program must offer new possibilities, rather than simply aping existing ones”.

Second, “the program must be in the hands of an artist who can be creative in the medium”. In this way the architect must be able to sketch, write, model or search for new images over the editing of existing drawings, in an easy, intuitive way in order to enable the architect to focus on the design problem and not on how to use the program [9]; so a digital sketching tool according to Do [29] “should recognize static drawing marks, such as simple geometric shapes, and their spatial relationships”; according to him, for building useful digital sketching tools for design, one must identify the dimensions of sketching. This includes identifying drawing components and design entities and the spatial relationships and transformations among them.

In order to better integrate the computer tools into the conceptual design process, Zhu et al [24] and Lawson [1], [10] state, the computer program must offer new possibilities and be able to include more functions and features rather than simply aping existing ones. Also, Gross and Do [12] suggest that, “digital support for creative design in architecture should include retrieval of visual references with similar forms. This aims to support three aspects of creativity: combining ideas from different sources, using visual metaphor and analogy, and expanding the search space to include innovative solutions”.

4. Pilot Study (Current Role of Digital Tools in Early Design Stage; Evaluation of Architectural Schools)

A pilot study is usually conducted to investigate the initial situation of research problem in hand and executed as planned for the future studies but on a smaller scale; so, as a preliminary study, the results cannot be generalized to the whole. This study in this section, aims to assess and understand how digital sketching tools are used in the early stages of design in architecture schools, as well as kinds of programs and software in real world. So, according to purpose of this section a pilot study was done to obtain the architecture instructors’ point of view. This survey was conducted via online questionnaire that was sent to architecture instructors’ emails that had research in this field and were randomly selected.

The questionnaire consists of three sections; in the *first* section, instructors were told to answer about their and their students designing tool(s) by four questions (as shown in Figure 5).

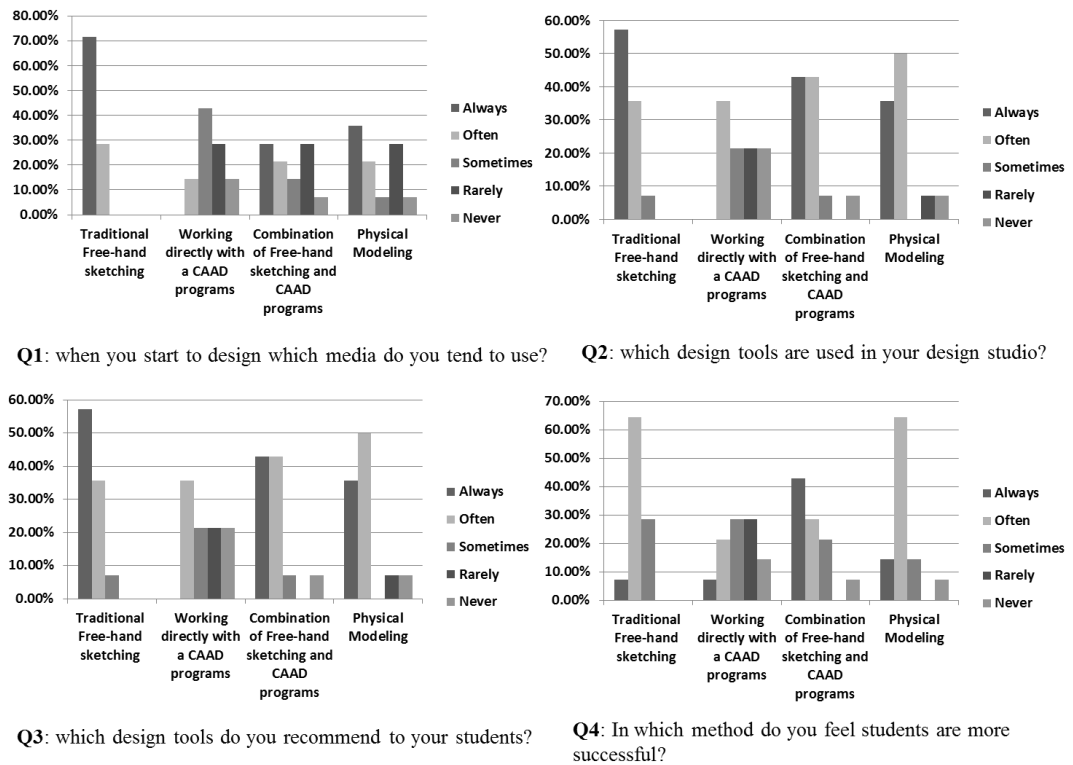


Figure 5 Questions of first section and percentage of answers

The responses of each participant were evaluated with the Likert analysis method. Findings demonstrate that the “traditional free-hand sketching” tool with the highest percentage (100%) has been the common designing tool among the instructors and their students; and “working directly with a CAAD program” got the lowest percentage (50%). (Shown in Table 1 and Figure 6)

Table 1 Percentage of tendencies of teachers to design tools

Design Tool	Positive Tendency	Negative Tendency
Traditional Free-hand sketching	100%	0%
Working directly with a CAAD program	50%	50%
Combination of Free-hand sketching and CAAD program	86%	14%

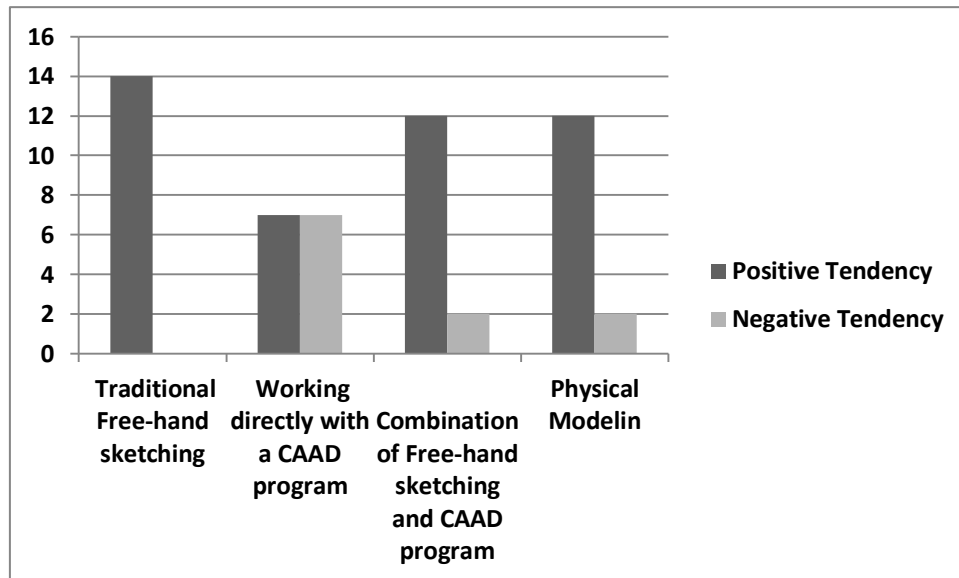


Figure 6 Percentage of tendency of teachers to design tools

In the *second* section of questioner, instructors were told to answer about digital media and its impact on the creativity and successfully of students (Figure 7). After evaluating the answers with the Likert analysis method, findings showed 64% of respondents had a positive tendency towards digital tools for supporting creativity, and 36% had a negative opinion.

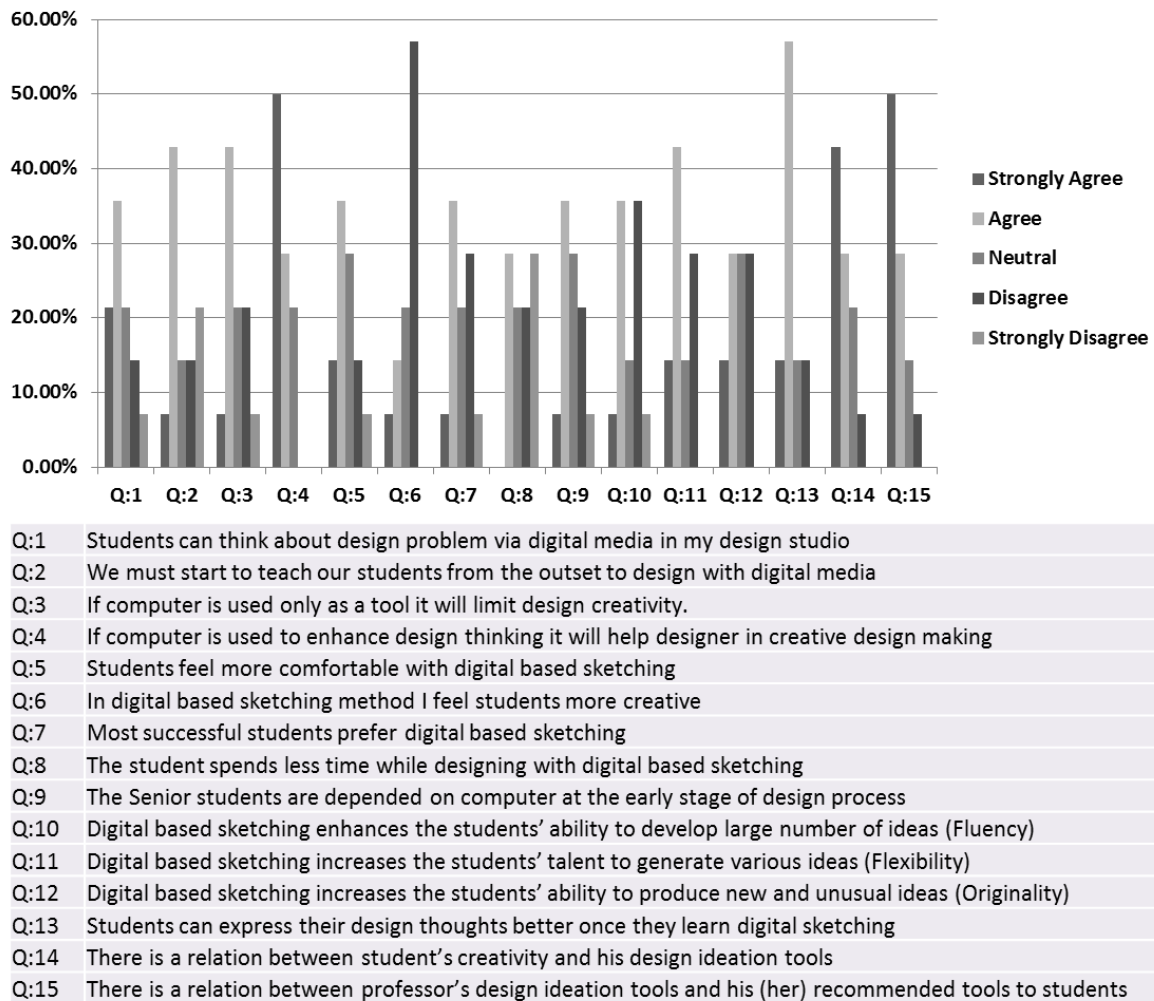


Figure 7 Questions to evaluate instructors' tendency to digital design tools

In the *third* section of survey, is asked of which digital design tools are used by instructors and their students. According to responses digital programs such as Sketchup, Photoshop, Sketchbook and AutoCAD are the common tools that the instructors and their students use and prefer for designing. Other digital tools such as Hype-3D, Archicad, Bailey Sketch (app), QsketchHDLite (app), Revit, Rhino, Balsamiq SketchiXML and Gambit Invision Axure programs, too, are mentioned.

4.1 Discussions

The results of the first section support the theoretical discussions that were posed in previous sections and this is a reflection of the professors' doubts over digital tools that instead of using them directly, they prefer the traditional freehand sketching or the combination of free-hand sketching and CAAD program. The result of 50% positive to 50% negative desire to use of digital tools, also confirm that

these tools are of interest and cannot be ignored. Although, instructors and students do not commonly use digital tools in the early design stages, but, the findings of second section indicate that, there is a tendency to use this technology among them, that with the advances in the user interface of digital programs and given the potential of these tools, it may be realized in the future times.

These results indicate that, freehand sketching is common design tools in early stages of design, but in many architectural schools, it is attempts to apply digital sketching tools especially among young students and educators. Findings of survey show some of instructors are strongly disagree with using of digital in the conceptual design, in contrast some of them believe that with advancing in digital technology, these tools should apply to the early design stages and replace paper based sketching. For this reasons, it seems that pen based digital systems and tools due to their similarity to conventional freehand sketching have been attention.

5. Conclusion

In this study, the current status of digital sketching in early design stage and their challenges in the educational filed, especially related to creativity are explored. Findings indicate that computer by new interfaces began to affect the thought process of designer in the early stage of design that has created a wave of discussions and challenges in architectural research and education. Recent developments in digital tools show a shift toward conceptual design interfaces; but they are still not commonly used in the early design stages. It seems that this returns, at the one hand, to the user interface of digital systems that encourage working with precision and detailed and do not allow vagueness and uncertainty, which plays an important role in conceptual design, and on the other hand, using of digital systems does not match the speed of thinking process of designer unlike the conventional freehand sketching. The emergence of some pen-based sketching systems, has created a strong desire - especially for the younger designers - to use them in the conceptual design phases, while the inadequacy of these software in encouraging ambiguity and creativity, has caused that, many of experienced designers and academics to doubt in using these tools, or even, entirely oppose to use them in the design thinking process.

Studies show despite to all of these, digital tools can support and enhance creativity. They can encourage creative behaviors and allow stimulating and exploring wide range of design alternatives by rethinking previous ideas and improve them. Therefore, many researchers attempt to propose recommendations to enhance digital systems or new ways of working with them in order to support creativity and sketching. According to researches to provide an interface that feels natural and close to traditional sketching and support creativity, the system must be able to resolve ambiguities and enable the architect to focus on the design problem and not on how to use the program; so a digital sketching tool should recognize marks, shapes and their spatial relationships by identifying the dimensions of sketching.

The results of pilot study too, confirm theoretical findings and suggest that the professors doubt over digital tools that instead of using them directly, they prefer the combination of freehand sketching and CAAD programs. But findings indicate that there is a tendency to use these tools among educators and their students. It is expected with the advances in user interface of digital programs, in future times, they will be used as designing and thinking tools in the early stages of architectural design at educational context.

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